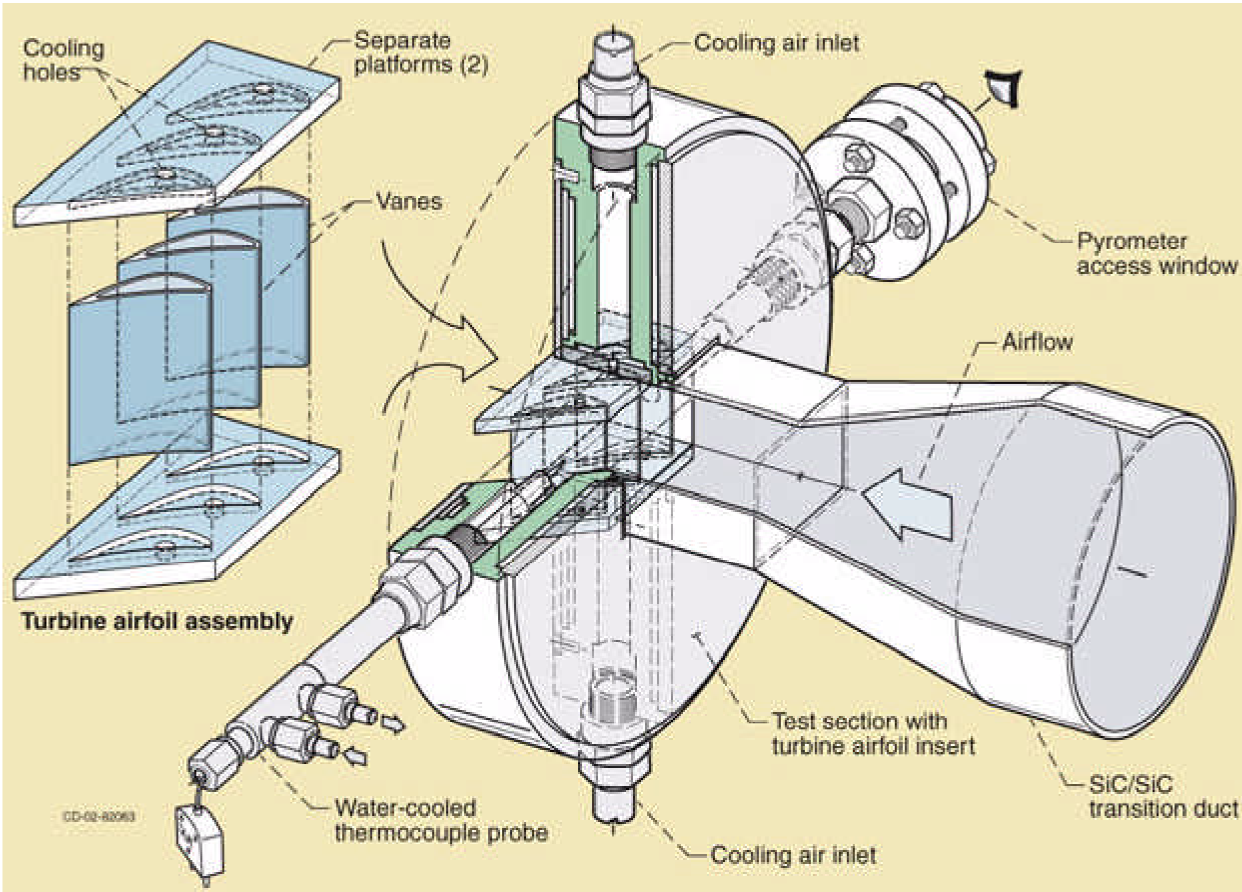
Ceramic Matrix Composite Vane Subelements Tested in a Gas Turbine Environment

The use of ceramic matrix composites (CMCs) as vanes for the next generation of turbine engines is under evaluation for improving engine performance, such as lowering emissions and enabling higher cycle efficiency, relative to today's engines with superalloy hot section components. Because of the high-temperature capability of this class of materials, CMC vanes would be able to operate with higher combustion exit temperatures than today's engines can. Alternatively, a potential vane cooling requirement reduction of 15 to 25 percent for a CMC, such as SiC/SiC, relative to a single-crystal superalloy would be realized if the combustion operation was not altered.

SiC/SiC vane subelement coated with an advanced environmental barrier coating and containing cooling holes in the trailing edge.

Vane subelements were fabricated from a silicon carbide fiber-reinforced silicon carbide matrix (SiC/SiC) composite and were coated with an advanced environmental barrier coating (EBC). So that the critical design features of a turbine airfoil could be addressed, the vane subelement geometry was derived from an aircraft engine vane. A fabrication technique was developed that enables vanes to be constructed using a high-strength silicon carbide fiber in the form of woven cloth. A unique cloth configuration was used to provide continuous fiber reinforcement at the sharp trailing edge, the most challenging feature for fabrication from a continuous-fiber-reinforced composite. A completed vane subelement is shown in the preceding photograph.

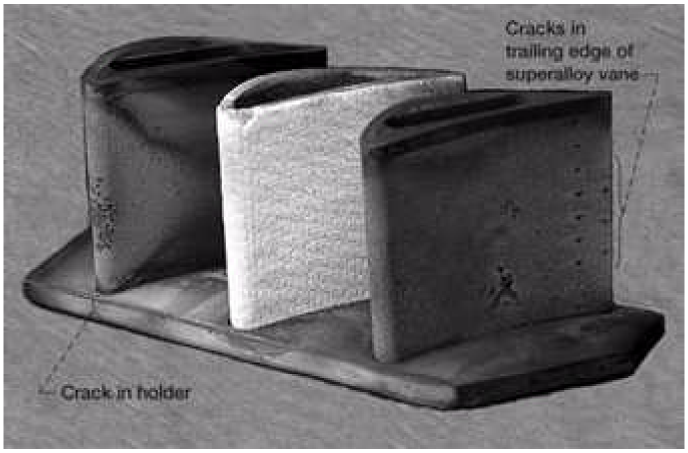
A test configuration for the vanes in a high-pressure gas turbine environment was designed and fabricated for the High Pressure Burner Rig at the NASA Glenn Research Center. Vane surface temperatures are measured using optical pyrometry, as shown in the following illustration. Test conditions include combustion flow at 60 m/sec and 6 atm, and temperatures above 1200 °C.



Configuration for testing SiC/SiC vanes in the High Pressure Burner Rig. (Illustration by Richard J. Czentorycki of InDyne, Inc.)

Long description.

Over 50 hr of rig testing on a SiC/SiC vane subelement have been completed. As shown in the final photograph, no degradation of the EBC-coated SiC/SiC vane occurred after testing at material temperatures up to 1200 °C. Metal vanes and rig hardware that were exposed to the same conditions had damage in the form of cracks and deformation, demonstrating the improved high-temperature capability of this ceramic composite over the metals used in today's gas turbine engines.



SiC/SiC vane with environmental barrier coating (center) after 20 hr of rig testing. Note the damage in the metal vanes and rig hardware.

Combustion gas flows down a circular cross-section duct. It is then directed to the test section via a transition duct. The transition duct's cross section changes from a 6-in. diameter to a 2- by 4-in. rectangular cross section. Three vanes are in the test section. The two outside vanes were fabricated from a high-temperature-capable alloy. The center vane is the SiC/SiC vane.

Find out more about this research:

Glenn's Environmental Durability Branch: http://www.grc.nasa.gov/WWW/EDB/
Glenn's Materials Division: http://www.grc.nasa.gov/WWW/MDWeb/

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